

PECULIARITIES OF HEAT PIPES APPLICATION FOR THERMAL CONTROL OF NICKEL-HYDROGEN STORAGE BATTERIES IN SPACECRAFTS

K. A. Goncharov

TzTT NPO named after S. A. Lavochkin,
24 Leningradskoye road, city of Khimky, Moscow region, Russia
Phone./Fax (495) 573-63-74; e-mail: heatpipe@berc.rssi.ru

V. V. Galkin, V. Y. Lapshin, S. D. Likhonosov

JSC «Saturn», 6, Solnechnaya Str., 350072, Krasnodar, Russia
e-mail: ikc@zit.kuban.ru; Phone: (861) 252-39-90; Fax:(861) 252-39-73, 252-39-43

Abstract

Heat pipes application (HP) in thermal control system (TCS) of nickel-hydrogen storage battery (NHSB) within spacecraft (S/C) improves mass characteristics of NHSB in combination with TCS, and brings flexibility into S/C arrangement. Heat pickup organization from NHSB directly by means of HP is provided in S/C «Yamal-200», «BelKA», «KazSat-2» and in NHSB 17NH-95. Options of TCS organization by means of HP are considered in terms of different S/Cs. Selection of optimal NHSB and TCS design is demonstrated depending on thermal environment.

KEYWORDS

Heat pipes, nickel-hydrogen storage battery, spacecraft, thermal control system.

INTRODUCTION

Temperature range of NHSB operation, providing optimal combination of high energy and life time characteristics, is from 0 to 15 °C. At the same time most of the S/C equipment operates at ambient temperature. Autonomous TCS is used more and more frequently to create comfortable thermal conditions for NHSB operation.

Traditionally this is obtained through NHSB installation onto the radiator. In this case the heat generated by nickel-hydrogen cells (NHC) dissipates to the bottom of NHSB housing and is taken away farther by radiator infrared radiation into space.

Heat pipes application expanded the possibilities of heat pickup organization and made it possible to select the most optimal scheme for the given conditions

OPTIONS OF AUTONOMOUS TCS NHSB ORGANIZATION

Thermal control system of NHSB influences not only battery thermal environment, but also its design configuration, and, as a consequence, its energy density, which is one of the major characteristics of storage batteries applied in spacecrafts.

Among different options of heat pickup organization in nickel-hydrogen storage batteries the main three ones may be distinguished:

1) traditional option implemented in S/C «KazSat», where heat pickup from nickel-hydrogen cell is made to the bottom of NHSB housing and further to radiator, installed directly against the bottom (Fig. 1 a);

2) option implemented in S/C «Yamal-200», where heat pickup from nickel-hydrogen cell is made to the perimeter of NHSB housing to axial heat pipes and then further by loop heat pipes to radiator (Fig. 1 b);

3) option implemented in S/C «KazSat-2», where heat pickup from nickel-hydrogen cell is made to the perimeter of NHSB to axial heat pipes and then further to radiator (Fig. 1 c);

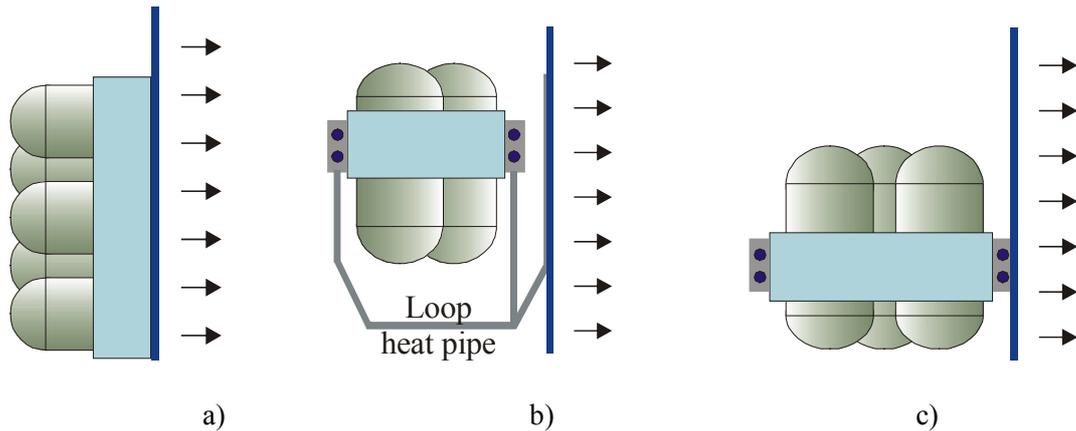


Fig. 1. Heat pickup schemes for NHSB in S/Cs «KazSat», «Yamal -200» and «KazSat-2»

In the first and third options thermal control is accomplished by heaters, located close to radiator.

In the second option thermal control, according to the basic scheme, is provided automatically by pressure regulator in loop heat pipes; this regulator is adjusted for the required temperature during manufacturing.

ADVANTAGES OF AXIAL HEAT PIPES APPLICATION

One of the main characteristics of NHSB is energy density – ratio of accumulated energy volume to mass.

Application of heat pipes located along the NHSB perimeter (options 2 and 3) allows to make radial heat pickup to the perimeter of NHSB housing and decrease noticeably its mass by “cutting off” its bottom. This is illustrated in Fig. 2. At radial heat pickup NHSB height is equal to the height of electrodes’ stack – heat-generating part of NHC. In case of axial heat pickup to the bottom of NHSB – housing height increases.

Furthermore, the advantage of radial heat pickup is the relatively small length of current collectors from electrodes’ stack to terminals, located at the top (Figure 2). Apart from mass saving this decreases internal resistance and, consequently, decreases heat generation and increases energy volume. In its turn lower heat generation requires smaller radiator area.

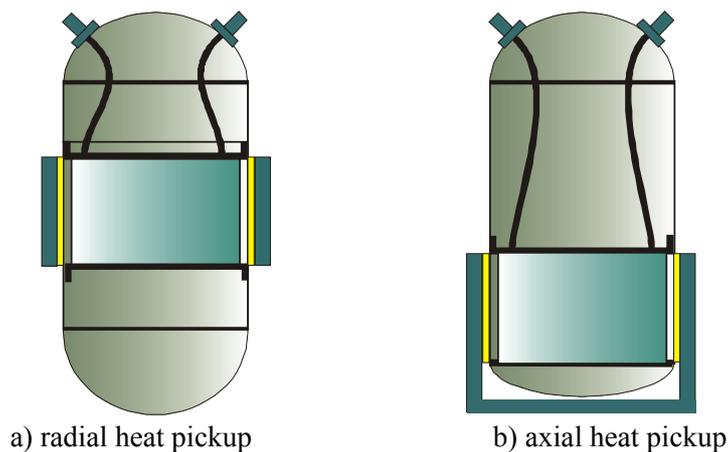


Fig. 2. Current collection dependence on heat pickup

Eventually advantages of heat pipes application outbalance their drawback – additional mass. This is illustrated in Table 1, where comparison of two options (1 and 3) is made, which were considered in the designing of NHSB and TCS for S/C «KazSat-2».As is obvious heat pipes application allowed to increase energy density of NHSB and TCS by 6 %.

Table 1. Comparative characteristics of NHSB 18NH-120K and TCS options

Characteristics	Option 1 of «KazSat» type	Option 3 «KazSat-2»
NHC characteristics		
Capacity, A·h	120	120
NHC mass, g	2035	2010
Average discharge voltage, mV	1210	1230
Energy density, W·h/kg	71	73
Mass characteristics of NHSB and TCS, kg		
NHC	36.8	36.4
NHSB housing	5.1	6.2
Power brackets	0.7	0.9
Covers	1.4	1.0
Multiplex and other	5.4	5.4
NHSB mass	50.3	49.0
Heat pipes	-	1.6
Radiator	4.8	2.0
NHSB +TCS	55.1	52.6
Power budget		
NHSB average discharge voltage, V	21.4	21.9
NHSB energy volume, W·h	2580	2620
NHSB energy density, W·h/kg	51	54
Energy density of NHSB +TCS, W·h/kg	47	50

ADVANTAGES OF LOOP HEAT PIPES APPLICATION

In case, when spacecraft configuration does not allow installing NHSB in close proximity to radiator, heat pickup from NHSB may be accomplished either by means of fluid cooling, or by means of heat pipes.

Fluid cooling is feasible, if common TCS ensures thermal conditions for all the equipment of the S/C. For autonomous TCS fluidal path with hydraulic pump will load it impermissibly. Therefore, in case, when NHSB and its radiator are separated in space, the most acceptable option is to use heat pipes, especially loop ones, like it is implemented in S/C «Ymal-200» and «BelKA» (Fig. 1 b) and is foreseen to be used in the development of NHSB and TCS for the People’s Republic of China.

As soon as loop heat pipes may be rather long, thin and flexible, NHSB may be located in any suitable place, independent of radiator location.

Besides, loop heat pipes have lower mass as compared to the other ones.

The other advantage of loop heat pipes is the possibility of thermal resistance regulation. This fact makes it possible to exclude from TCS powerful heaters, which are used in other schemes for maintaining the required temperature at small loads, and, consequently, at small heat-generation.

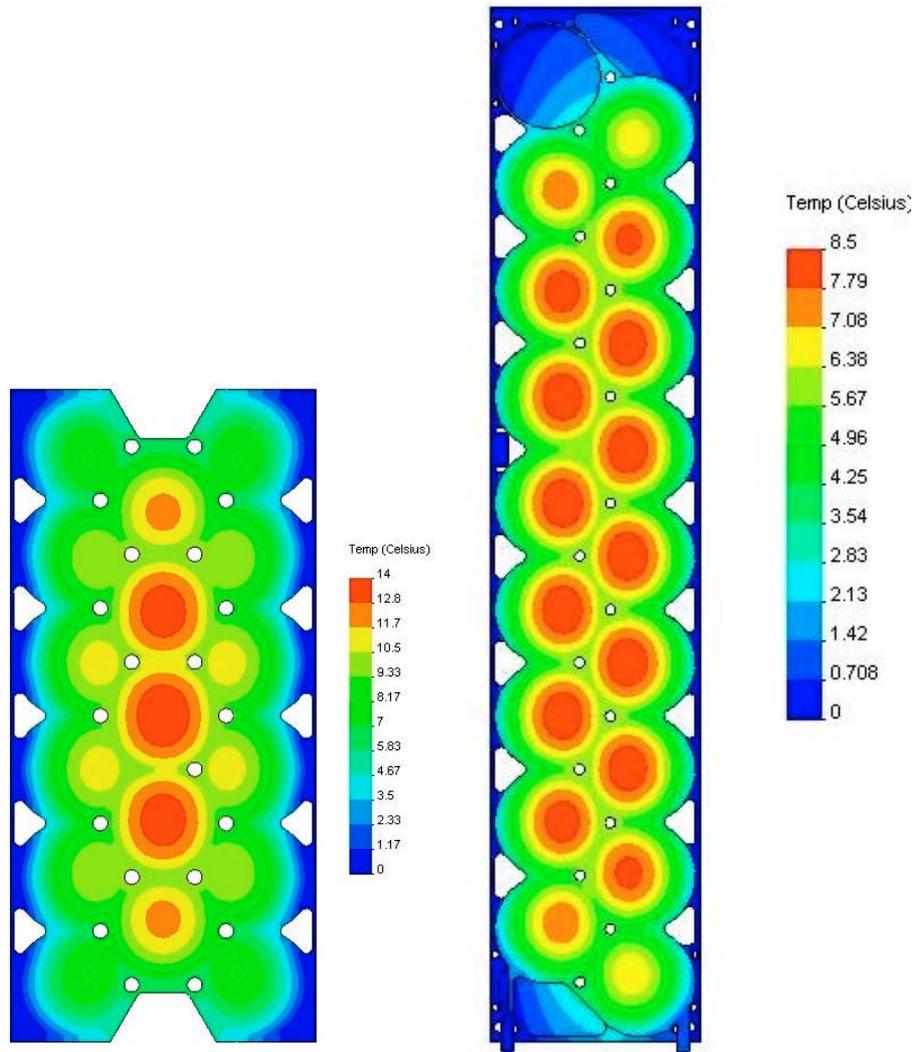
In this case thermal control is made automatically by pressure regulator in loop heat pipes; this regulator is adjusted for the required temperature during manufacturing. Thereby TCS reliability is increased and spacecraft energetics is saved.

PECULIARITIES OF NHSB DESIGN WITH HEAT PIPES APPLICATION

At the same time and especially for high power NHSB there is limitation for the number of NHC strings within NHSB.

This may be demonstrated on an example of NHSB 17NH-95 development for Tianjin Institute of Current Power Supplies (People’s Republic of China). The initial version provided two strings design, then on the base of mechanical analysis results the three strings option was considered. However, thermal analysis of three strings option showed that at given operating modes of NHSB out-of-limit

temperature gradients appear in it (Fig. 3 and Table 2). Therefore the decision was made to get back to two strings version, having reinforced it with brackets in the middle.



a) three strings configuration of NHSB b) two strings configuration of NHSB

Fig. 3. Average per coil temperature distribution in NHSB

Table 2. Comparative temperature characteristics of three strings and two strings NHSB design

Characteristics	Three strings version		Two strings version		Limit
	Failure free operation	Single failure of NHC	Failure free operation	Single failure of NHC	
Maximum temperature gradient inside NHC, °C	11	14	6	6.8	7
Maximum temperature gradient between NHCs, °C	6	10	1.4	2.3	3

CONCLUSION

The selection of a particular option of thermal control system organization depends in many ways upon S/C developer, but certainly heat pipes application improves noticeably NHSB thermal conditions and, which is more important, mass characteristics of NHSB together with TCS.